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Tunable room-temperature single-photon emission at telecom wavelengths from sp^3 defects in carbon nanotubes

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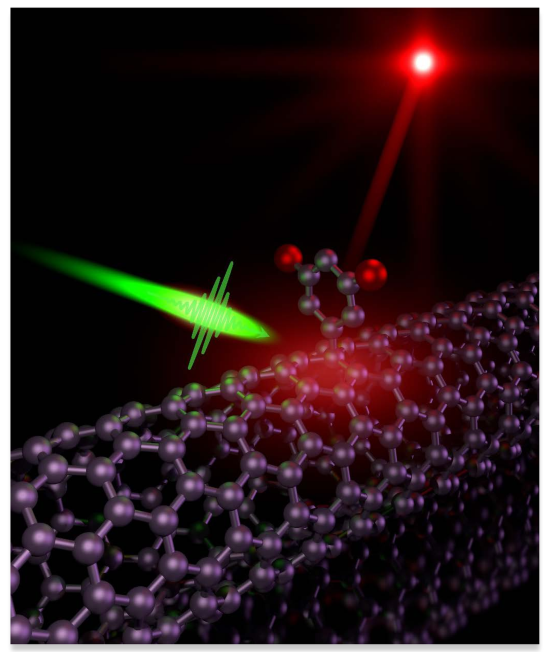
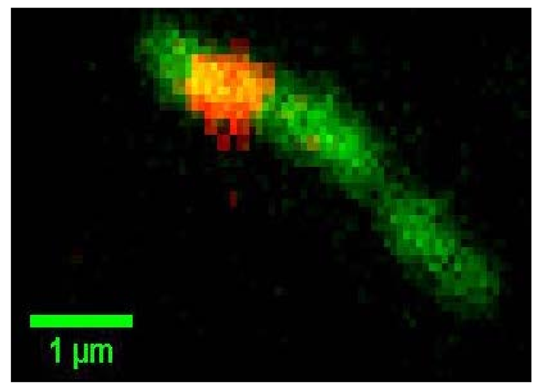
Introduction

Single-photon sources (SPSs) are the enabling materials required for quantum photonics, quantum information processing and quantum computing. Developing room-temperature SPS at telecom band (1.3-1.55 μm) remains a significant material challenge.



Harnessing exciton localization at defect site in low-dimensional nanomaterials such as single wall carbon nanotube (SWCNT) is a promising route to achieve room-T single-photo emission (SPE).

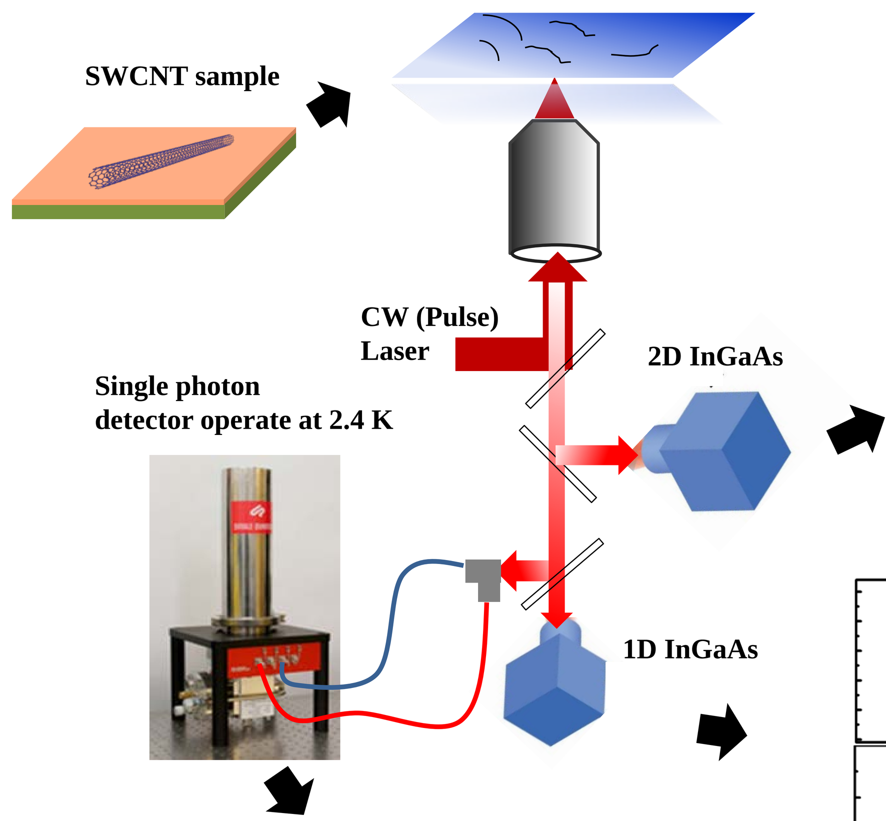


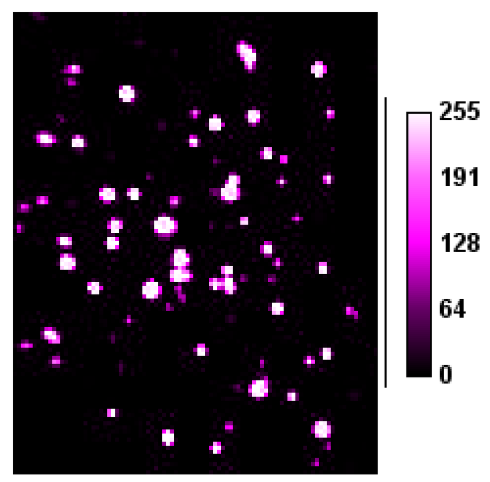
In this work, we demonstrate that solitary sp^3 defects on SWCNTs paired with nanotube structural diversity can generate room-T SPE spanning the entire telecom band.

[1] X. Ma et.al. *Nat. Nanotechnol.*, **2015**, *10*, 671. [2] Nicholai F. Hartmann et al. *Nanoscale.*, **2015**, *7*, 20521. [3] Y. Piao et.al. *Nature Chem.*, **2013**, *10*, 840.

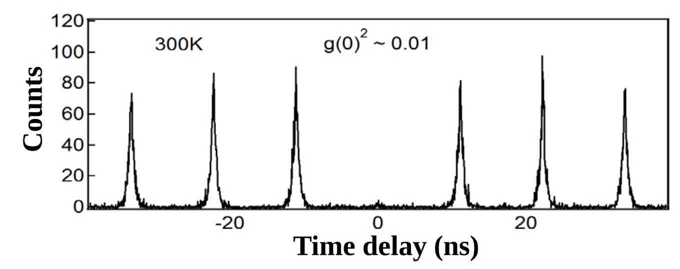
Experimental Setup

- Home-made confocal microscope system
- Superconducting nanowire single photon detector
- Single CNT optical imaging and spectroscopy
- Quantum optical measurements of individual CNTs

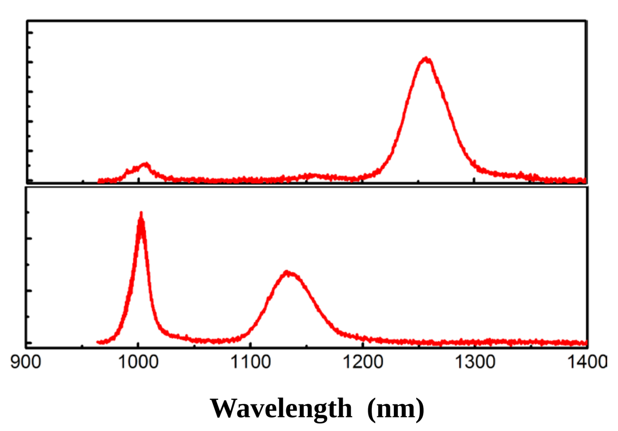




Wide field image



Second order photon- correlation measurement

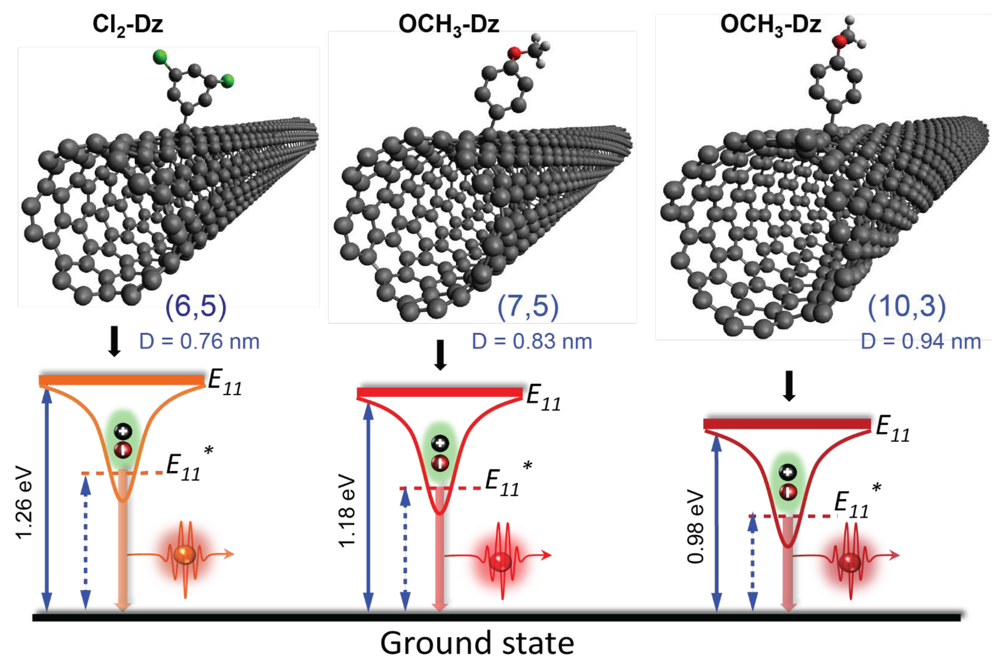


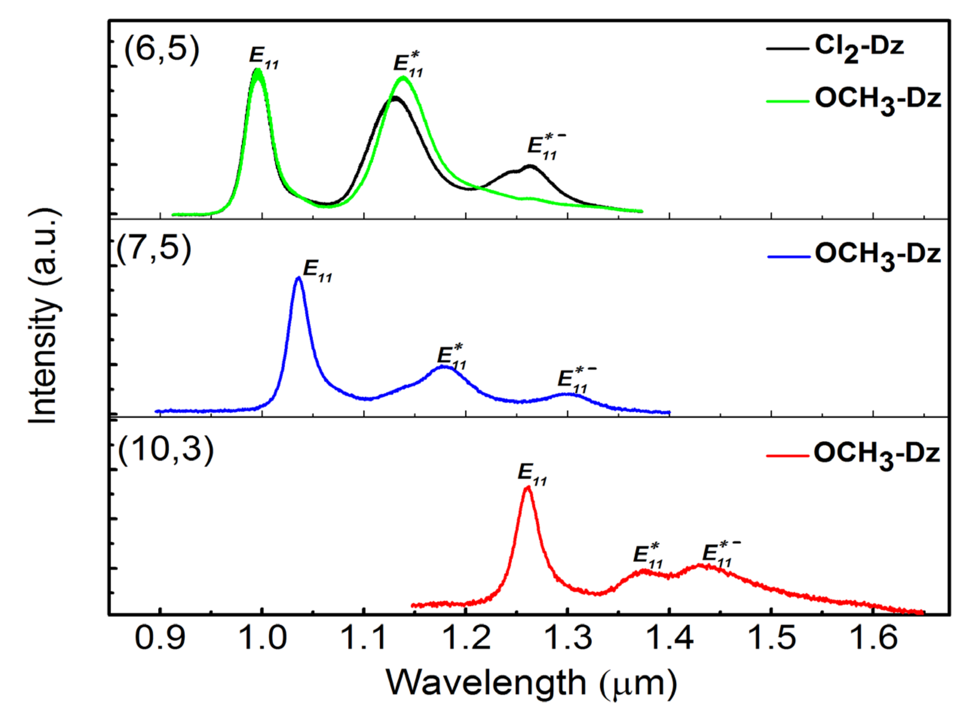
Individual doped CNT PL spectra

Xiaowei He et.al., *Nat. Photon*, **2017**, *11*, 577.

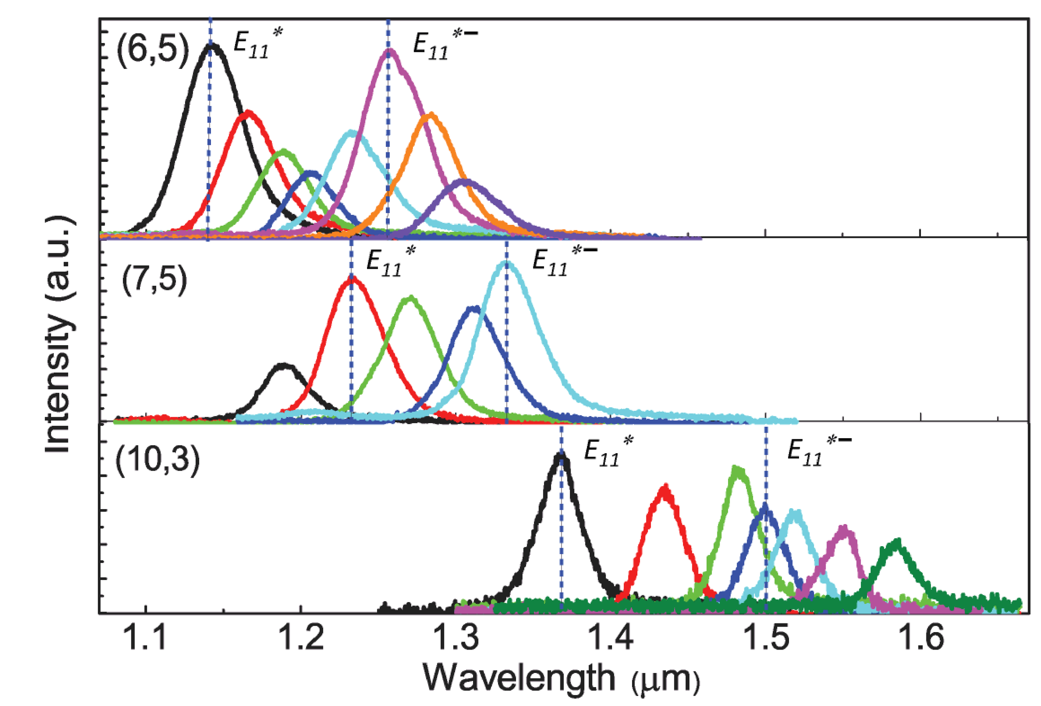
Tune Defect-emission Wavelength

- Generation of sp^3 defects on CNTs by solution based chemical doping — aryl diazonium functionalization
- Introduction of new red shifted emitting states E_{11}* and E_{11}*⁻
- Tuning the defect-emission wavelength to telecom band by selecting CNTs with different diameters



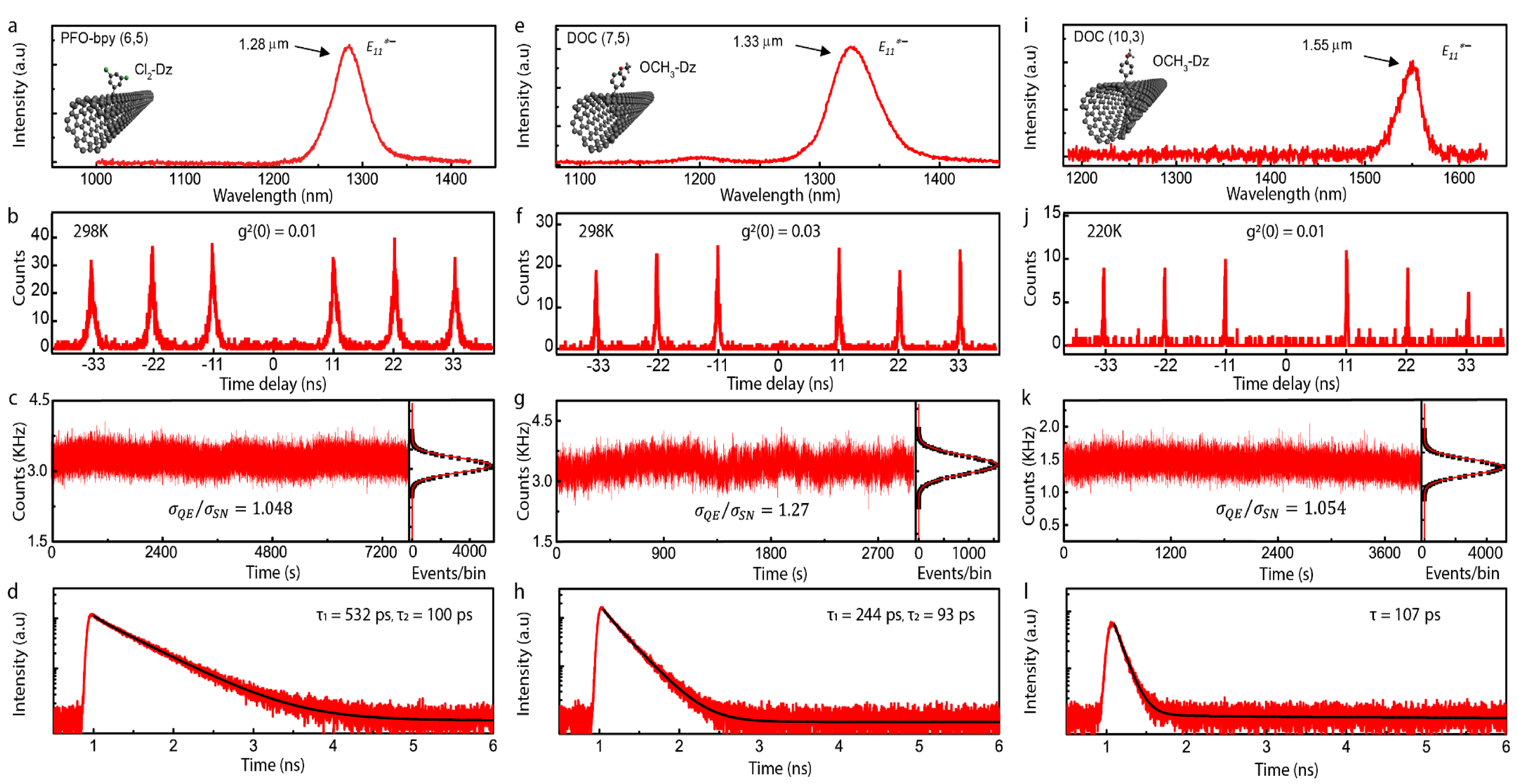


Ensemble PL spectra of doped CNTs



Individual defect emissions of doped CNTs

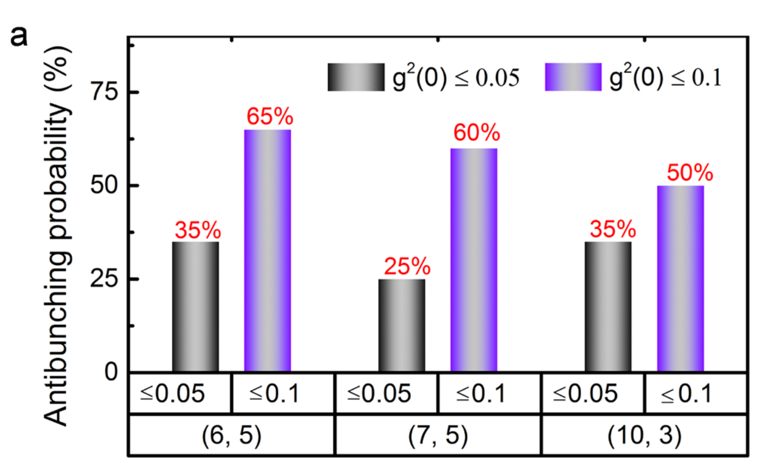
Room-T SPE at Telecom Band

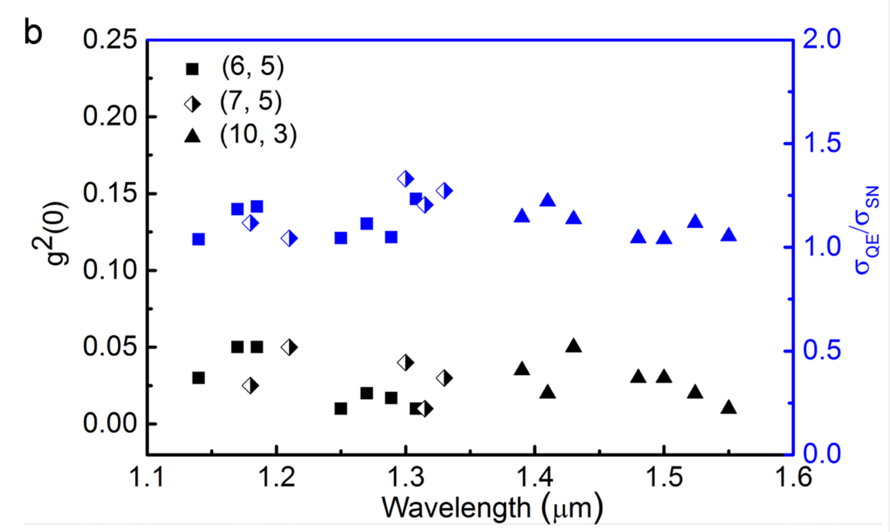


Xiaowei He et.al., *Nat. Photon*, **2017**, *11*, 577.

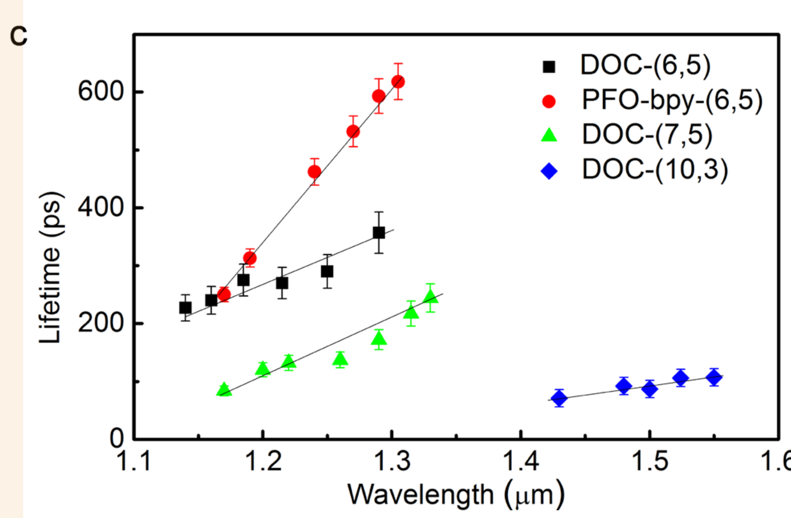
- ▶ Ultra high single photon purity with $g^2(0) \sim 0.01$.
- ▶ Exceptional emission stability approaching short noise limitation.
- ▶ Room-T operation at Telecom O and C band.

Trends in Quantum Emission Behaviors





- ▶ Above 60% of the doped CNTs show the $g^2(0)$ lower than 0.1.
- ▶ High emission stability and high single photon purity exist for all three chiralities with emission range from 1.1 to 1.6 μm.
- ▶ The life time of defect emission shows dependence on tube diameters, the larger the diameter, the shorter the life time.



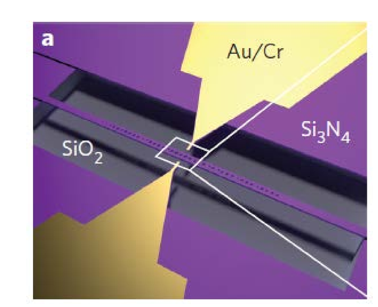
Xiaowei He et.al., *Nat. Photon*, **2017**, *11*, 577.

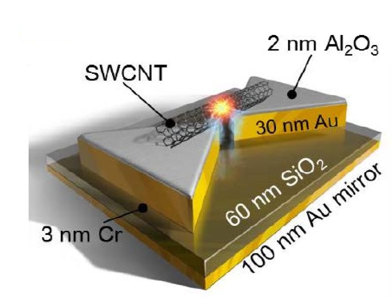
Summary and Outlook

- ▶ Room-T operation at critical telecom wavelength (1.3 and 1.55 μm).
- ▶ High single photon purity (~99%)
- ▶ Short noise limited emission ability (σ_{QE}/σ_{SN} ~1)
- ▶ High emission rates (10^{-5}-10^{-7} s^{-1})

What is next?

- Developing electrical-driven SPEs from doped CNTs [4]
- Investigating photon Indistinguishability of the defect emission by coupling to plasmonic civilities [5]
- Realizing wavelength-controllable defect emission through diverse structures of CNTs





[4] Svetlana Khasminskaya et.al., *Nat. Photon*, **2016**, *10*, 420.
[5] Yue Luo et.al., *Nature commun*, under review.

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